

CREW AND THERMAL SYSTEMS DIVISION
NASA - LYNDON B. JOHNSON SPACE CENTER

**Hazard Analysis for Building 34
Vacuum Glove Box Assembly**

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REVISIONS				
REVISION LETTER/DATE	PREPARER	APPROVALS		AUTHORZIED
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Change Record

Revision	Date	Originator	Description
A	09/22/2010	John Harris	Initial Release
B	03/13/2014	Ian Meginnis	Changes were made to reflect updates to the vacuum pump and relief valve sizing. Changed formatting of hazard analysis worksheets.

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1.0 Introduction

One of the characteristics of an effective safety program is the recognition and control of hazards before mishaps or failures occur. Conducting potentially hazardous tests necessitates a thorough hazard analysis in order to prevent injury to personnel, and to prevent damage to facilities and equipment.

The primary purpose of this hazard analysis is to define and address the potential hazards and controls associated with the Building 34 Vacuum Glove Box Assembly, and to provide the applicable team of personnel with the documented results. It is imperative that each member of the team be familiar with the hazards and controls associated with his/her particular tasks, assignments and activities while interfacing with facility test systems, equipment and hardware.

In fulfillment of the stated purposes, the goal of this hazard analysis is to identify all hazards that have the potential to harm personnel, damage the facility or its test systems or equipment, test articles, Government or personal property, or the environment. This analysis may also assess the significance and risk, when applicable, of lost test objectives when substantial monetary value is involved. The hazards, causes, controls, verifications, and risk assessment codes have been documented on the hazard analysis work sheets in Appendix A of this document.

The preparation and development of this report is in accordance with JPR 1700.1, "JSC Safety and Health Handbook" and JSC 17773 Rev D "Instructions for Preparation of Hazard Analysis for JSC Ground Operations".

2.0 Purpose

The purpose of this document is to present the potential hazards involved in operations of the Building 34 Vacuum Glove Box Assembly. The hazards listed in this document are specific to Glove Box and Glove Assembly operations only; each supporting facility or requestor is responsible for task specific Hazard Analysis. A "hazard" is defined as any condition that has the potential for harming personnel or equipment.

3.0 Scope

As applicable, the scope of this safety assessment considers/reviews the following elements of the test/hardware system.

- A) Test System/Facility Hardware – Structural, Mechanical, Electrical, Chemical, Test Environment, Static/Dynamic Energies, Materials
- B) Test Personnel training and interaction with hardware, facility and/or test system
- C) Test Procedures, Equipment Operating Instructions, Check Lists, Equipment/Component Configurations, Drawings and Schematics

4.0 References

Note: All references must be reviewed prior to use to verify/confirm that the document is the latest revision.

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4.1 Documents

Document Number	Revision	Document Title
CTSD-ADV-804	B	Building 34 Glove Box Functional Check-Out
CTSD-ADV-826	B	Building 34 Glove Box Operations
CTSD-SH-998	D	CTSD Chemical Hygiene Plan
EA-WI-024	A	General Operating Procedures Manual for EA Testing Facilities
JPR 1700.1	J	JSC Safety and Health Handbook
JPR 1710.13	E	Design, Inspection, Certification of Pressure Vessels and Pressurized Systems
JSC 17773	D	Instructions for Preparing Hazard Analysis for JSC Ground Operations
NFPA 70		National Electrical Code (NEC)
STB-E-083	A	CTSD Materials Control Procedure and Materials Selection Criteria
SW-E-0002	E	Ground Support Equipment General Design Requirement
STB-F-586	B	Building 7 General Emergency Preparedness Plan and Evacuation Procedures
CTSD-INST-004	A	Building 34 Emergency Action Plan
WI-EC-4.10-1	A	EVA and Spacesuit System Branch Test Operations
NPR 8715.3		NASA General Safety Program Requirements

4.2 Drawings/Schematics

Drawing Number	Sheet#	Revision	Title
A27-M00000	1	C	Building 34 Glove Box Mechanical Schematic
A27-E00000	1	C	Building 34 Glove Box Circuit Wiring Diagram
SED36129264	1,2	B	Glove Box Part Drawing

5.0 Symbols and Abbreviations

Symbols & Abbreviations	Explanation
EVA	Extra Vehicular Activity
GSE	Ground Support Equipment
HA	Hazard Analysis
HAWS	Hazard Analysis Worksheet
TRR	Technical Readiness Review
PSIA	Pounds per square inch – absolute
PSID	Pounds per square inch – delta
PSIG	Pounds per square inch – gauge
PSMO	Pressure System Managers Office

6.0 Definitions

The following definitions are vital to an understanding of the requirements contained in this document:

- a. Hazard — An unsafe or unhealthful condition that could lead to a mishap if it is not corrected.

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- b. Severity — The subjective estimate of worst credible outcome in terms of potential personnel injury, equipment/facility damage, and monetary losses. Consequence severity classes are defined as follows.

Class I – **Catastrophic**: A condition that may cause death or permanently disabling injury, facility destruction on the ground, or loss of crew, major systems, or vehicle during the mission; schedule slippage causing launch window to be missed; cost overrun greater than 50% of planned cost.

Class II – **Critical**: A condition that may cause severe injury or occupational illness, or major property damage to facilities, systems, equipment, or flight hardware; schedule slippage causing launch date to be missed; cost overrun between 15% and not exceeding 50% of planned cost.

Class III – **Moderate**: A condition that may cause minor injury or occupational illness, or minor property damage to facilities, systems, equipment, or flight hardware; internal schedule slip that does not impact launch date; cost overrun between 2% and not exceeding 15% of planned cost.

Class IV – **Negligible**: A condition that could cause the need for minor first-aid treatment but would not adversely affect personal safety or health; damage to facilities, equipment, or flight hardware more than normal wear and tear level; internal schedule slip that does not impact internal development milestones; cost overrun less than 2% of planned cost.

- c. Probability — The relative likelihood a hazard may occur. The complete likelihood range is separated into intervals for additional classification. It is important to note that even though quantitative probability intervals are listed in this document they are only for numeric comparison and that the actual probability or likelihood is derived by subjective estimations of a qualitative nature. The hazard likelihood categories are defined as follows.

Probability A – **Likely to occur** – (e.g., $1.0 \geq \text{Probability} > 0.1$)

Probability B – **Probably will occur** – (e.g., $0.1 \geq \text{Probability} > 0.01$)

Probability C – **May occur** – (e.g., $0.01 \geq \text{Probability} > 0.001$)

Probability D – **Unlikely to occur** – (e.g., $0.001 \geq \text{Probability} > 0.000001$)

Probability E – **Improbable** – (e.g., $0.000001 \geq \text{Probability}$)

- d. Risk Assessment Code (RAC) — The risk assessment code is the numerical value that represents the hazard risk associated with a given task, project, test, or equipment and is the point of intersection of the consequence severity estimate and the likelihood estimate on the RAC matrix.
- e. Risk Assessment Code (RAC) Matrix — A matrix made up of likelihood estimates, consequence severity estimates and risk assessment codes. The matrix is used to derive the risk assessment code once the consequence and likelihood have been determined.

The RAC matrix is defined as follows:

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Table 1 – Risk Assessment Code Matrix

CONSEQUENCE CLASS	LIKELIHOOD ESTIMATE				
	A	B	C	D	E
I	1	1	2	3	4
II	1	2	3	4	5
III	2	3	4	5	6
IV	3	4	5	6	7

The table below specifies the required action(s) for each RAC.

Table 2 – RAC Action Table

RAC	Action
1	Unacceptable – All operations must cease immediately until the hazard is corrected or until temporary controls are in place and permanent controls are in work. A safety or health professional must stay at the scene at least until temporary controls are in place. RAC 1 hazards have the highest priority for hazard controls.
2	Undesirable – All operations must cease immediately until the hazard is corrected or until temporary controls are in place and permanent controls are in work. RAC 2 hazards are next in priority after RAC 1 hazards for control. Program Manager (Directorate level), Organizational Director, or equivalent management is authorized to accept the risk with adequate justification
3	Acceptable with controls – Division Chief or equivalent management is authorized to accept the risk with adequate justification
4-7	Acceptable with controls – Branch Chief or equivalent management is authorized to accept the risk with adequate justification

- f. Hazard Disposition — The status of a hazard after controls are in place. Hazard Dispositions are utilized in this analysis, documented at the bottom of each hazard analysis worksheet, to supplement the risk assessment codes and to further describe the control or status of the hazard. The disposition criteria are defined as follows:

Open/no action — A hazard exists in the system, and no controlling equipment or procedures have been implemented to minimize the hazard.

Closed/controlled — A hazard exists in the system, and appropriate mechanical/electrical/procedural actions have been taken to reduce the hazard to a minimal level.

Closed/eliminated — A hazard that is no longer in the system because it has been eliminated.

Closed/accepted — A hazard of RAC 2 or 3 after controls whose risk has been accepted by NASA management.

- g. Hazard Summary — A list of the hazard categories/titles with before and after control RAC's.

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- h. Verification — The validation method or process that confirms the hazard control. Verifications of the hazard controls are identified via review of test procedures, equipment operating instructions and check lists, test system drawings and schematics, personnel training records, applicable JSC, EA, Division, and Branch work instructions and operating procedures, inspection of test equipment/area and interviews with facility engineers, technicians, test directors, and management.
- i. Hazard Analysis Worksheet (HAW) — Tables in the hazard analysis used to document specific information regarding each hazard or hazard category, such as hazard title/description/consequence, system, sub-system, RAC, hazard causes, controls, verifications, remarks, and hazard disposition. There is only one hazard category/title per HAW.

7.0 Hazard Identification Criteria

As applicable, the following sources were utilized in developing the potential hazards, cause, controls and verifications in this Hazard Analysis:

- System design drawings, schematics, and Configuration Change Orders
- Detailed Test Procedures, Task Performance Sheets, Checklists, Preventative Maintenance Instruction
- Test system, equipment/hardware, and facility visual inspections
- Review of lessons learned and accident/mishap/injury reports
- Discussion with the test team, design engineers, test article experts, and management

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8.0 Discussion/Description

8.1 Test System

The Building 34 Vacuum Glove Box Assembly, system numbers: A27-M00000 (mechanical) and A27-E00000 (electrical), is a transparent pressure vessel. The glove box can structurally withstand negative pressures up to 14.7 PSID, but a design MAWP of 9.0 PSID was selected to protect ancillary hardware that is used with the glove box. The system is designed to operate with one technician. A pressure gauge is mounted on the display panel and shows the differential pressure between the glove box and the ambient pressure environment. The end caps of the glove box are removable to allow installation/removal of test equipment inside the glove box. Two arm ports are located in the middle of the cylinder and include arm bearing blanking plates. The glove box is mounted on a height-adjustable stand which positions the arm ports at a subject's shoulder level. A vacuum pump is used for reducing the pressure in the glove box. Class III arms with arm bearings and wrist disconnects are used to evaluate space suit gloves and other hardware.

The glove box is shown in Figure 1.



Figure 1 – Building 34 Vacuum Glove Box System.

8.2 Test Article

The glove box can perform a variety of tests that include, but are not limited to, glove fit checks, space suit tool evaluations, prototype hardware evaluations, and certification testing. Generic tests (glove fit checks, EVA tool evaluations, etc) are covered under the Advanced Suit Lab (ASL) annual TRR. A dedicated TRR is required for tests that introduce new hazards to the glove box system.

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9.0 Hazard Summary

Table 3 summarizes the potential system hazards and risk assessment codes associated with this facility equipment, hardware, task, and/or test system. The details of each hazard, such as the specific hazard causes, controls and verifications, are documented on the hazard analysis work sheets in Appendix A.

Table 3 – Hazard Summary Table

Hazard		Consequence/Likelihood/RAC	
		Before Controls	After Controls
1	Structural Failure	III/C/4	III/D/5
2	Contamination	II/A/1	II/C/3
3	Electrocution	I/C/2	I/D/3
4	Smoke/Fire	III/C/4	III/D/5
5	General Personnel Injury	II/B/2	II/D/4
6	Sharp Edges/Corners	II/C/3	II/D/4

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Appendix A
HAZARD ANALYSIS WORKSHEETS

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Hazard Analysis – Structural Failure

Nr.	Hazard	Cause	Effect	RAC Before Controls	Controls	Verification	RAC After Controls
1.	Structural Failure	Over-depressurization of glove box caused by malfunctioning gage/relief valve/regulator	Test hardware damage	III/C/4	Relief valve, as bench tested, set to 8.9 ± 0.1 PSID, installed internally to glove box and vented to ambient. Gloves and arm segments used with the glove box must have an MAWP of at least 9 PSID.	A27-M00000	III/D/5
			Personnel injury		Relief valve is calibrated every 5 years, per JPR1710.13.	CTSD-ADV-804, Section 1.0	
					Glove box receives Class 1 inspection every 2 years, per JPR1710.13.	CTSD-ADV-804, Section 1.0	
					Gage and regulator are evaluated for functionality at least 30 days prior to performing a test with glove box.	CTSD-ADV-804	
		Over-depressurization of the glove box caused by faulty sizing of relief valve			PSMO design review has been completed on glove box system, per JPR1710.13.	CTSD-ADV-804, Section 1.0	
		Faulty design of glove box structure			Glove box assembly design has been reviewed and approved by JSC structural analysts.	SED36129264	
		Negligent operation			Operating procedures are required to operate the glove box.	CTSD-ADV-826	
					Only qualified personnel are authorized to operate the glove box.	Technician certification letters on file with EC5	

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Hazard Analysis – Contamination

Nr.	Hazard	Cause	Effect	RAC Before Controls	Controls	Verification	RAC After Controls
2.	Contamination to glove box and/or test article	Foreign particulate introduced to glove box and/or test articles	Test hardware damage Personnel injury	II/A/I	Only qualified personnel are authorized to operate glove box.	Technician certification letters on file with EC5	II/C/3
					Glove box and test setup are inspected prior to use.	CTSD-ADV-826, Section 1.0	
					Functional checkout is completed at least 30 days prior to glove box testing.	CTSD-ADV-826, Scope	
		Foreign particulate introduced to vacuum pump	Vacuum pump damage		Filter installed upstream of vacuum pump.	A27-M00000	

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Hazard Analysis – Electrocution

Nr.	Hazard	Cause	Effect	RAC Before Controls	Controls	Verification	RAC After Controls
3.	Electrocution	Personnel contact with exposed wires	Electrocution	I/C/2	Electrical connections and terminals are not exposed.	CTSD-ADV-804, Section 1.0 and CTSD-ADV-826, Section 1.0	I/D/3
					Glove box assembly and test setup are inspected prior to use.		
		Short circuit			Electrical design and build-up has been reviewed and approved by EC5 electrical engineer.	A27-E00000	
		Frayed wires			Electrical devices' cases are grounded GFCI protection is incorporated into the glove box assembly design.	A27-E00000	

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Hazard Analysis – Smoke/Fire

Nr.	Hazard	Cause	Effect	RAC Before Controls	Controls	Verification	RAC After Controls
4.	Smoke/Fire	Ignition or non-compatible materials present in glove box	Damage to test equipment	III/C/4	Hazardous materials are not used in glove box without prior approval by TRR chair.	CTSD-ADV-826, Scope	III/D/5
		Electrical short circuit	Personnel injury		Glove box assembly and test setup are inspected prior to use.	CTSD-ADV-804, Section 1.0 and CTSD-ADV-826, Section 1.0	
					Electrical design and build-up has been reviewed and approved by EC5 electrical engineer.	A27-E00000	
		Vacuum pump overheating			Vacuum pump includes automatic temperature shutoff	A27-E00000	

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Hazard Analysis – General Personnel Injury

Nr.	Hazard	Cause	Effect	RAC Before Controls	Controls	Verification	RAC After Controls
5.	General Personnel Injury	Slips, trips, falls, pinch points, etc.	Personnel injury	II/B/2	Glove box assembly and test setup are inspected prior to use.	CTSD-ADV-804, Section 1.0 and CTSD-ADV-826, Section 1.0	II/D/4
					Safety glasses are required during operation of glove box.	CTSD-ADV-804, Scope and CTSD-ADV-826, Scope	
		Equipment/Machinery causes excessive noise			Functional checkout is completed at least 30 days prior to glove box testing.	CTSD-ADV-804, Scope	
		Pinch point caused by adjusting height of glove box			Only qualified personnel are authorized to operate glove box.	Technician certification letters on file with EC5.	
					Procedures ensure all test support personnel are clear of glove box prior to adjust of glove box.	CTSD-ADV-804, Section 3.0 and CTSD-ADV-826, Section 2.0	
		Glove box tipping over during transportation	Personnel injury		Only qualified personnel are authorized to operate glove box.	Technician certification letters on file with EC5.	
			Hardware damage				

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Hazard Analysis – Sharp Edges/Corners

Nr.	Hazard	Cause	Effect	RAC Before Controls	Controls	Verification	RAC After Controls
6.	Sharp Edges/Corners	Contact with sharp edges or protrusions	Personnel injury	II/C/3	Glove box, gloves, GSE, and support hardware are inspected to verify that assemblies are free of sharp edges and corners.	CTSD-ADV-826, Section 1.0	II/D/4
			Hardware Damage		Technicians are trained for sharp edge inspections where/as needed.	Technician certification letters on file with EC5.	